International Council for the
Exploration of the Sea

C.M. 1989/B:9
Fish Capture Committee
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Bergen Echo Integrator: An Introduction

by

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ABSTRACT

The design of a new echo integrator system is outlined. The B.E.I. is based on preprocessed data from the new SIMRAD EK500 scientific acoustic measurement system. Raw data are displayed and interpreted on a graphics workstation by means of a specially designed man-machine interface. Principles guiding the design are that the software be machine-independent and be based on internationally approved standards, e.g., UNIX, C, X-Windows, SQL database, GKS. The realization of this and the first sea trials are described. The potential for future developments is discussed.

RESUME

Nous présentons dans les grandes lignes un noveau système à écho intégré. Le B.E.I. se base sur les données prétraitées provenant du nouveau système de mesurage acoustique scientifique SIMRAD EK500. Les données brutes sont affichées et interprétées sur un poste de travail graphique au moyen d´un interface homme-machine spécialement conçu pour cet usage. Les principes ayant guidé cette conception sont que le logiciel doit être indépendant de la machine et se baser sur des normes internationales, telles que UNIX, C, X-WINDOWS, base de données SQL, GKS. Nous en décrivons la réalisation et les premiers essais en mer. On discutera des développements futurs potentiels.

INTRODUCTION

The Bergen Echo Integrator represents the latest development in a process that has been ongoing in the Bergen milieu over the past several decades. The goal has been to develop the best possible tool for fish stock assessment. This tool consists of both instrumentation and methods. Earlier developments included analog integrators with the subjective interpretation of echograms [1] and integrators based on digital minicomputers [2].

B.E.I. is based on use of a graphics workstation as the central unit in an on-board computer network [3].

The most important data source is the signal from the SIMRAD EK500, scientific sounder system [4]. Preprocessed data with high resolution are logged from the EK500 and stored in mass storage. The data can be read from the mass storage anytime and can be displayed and interpreted on the graphics workstation.

DESIGN GOALS

The system should, as its primary task, take care of the postprocessing of the huge amount of data received from the EK500, but it should, as secondary tasks, be able to receive, process, and present data from a number of other data sources. In order to economize in cabling and to achive high capacity with a minimum of limitations to future expansions, it was decided on SIMRAD Subsea´s suggestion to communicate via a Local Area Network (LAN). This is in accordance with modern system architecture, and most computer manufacturers offer network interfaces as standard accessories.

An important goal has been to design the most user-friendly man-machine interface possible. Much effort has been expended to make use of the experience that scientists and technicians at the institute have accumulated at sea over many years.

The system should be flexible and open for future expansion. It was decided to aim at a high technological level, and computer graphics should be prominent. To secure continuity in future developments, only internationally approved standards are employed. These include UNIX operating system, X-Windows standardized window system, TCP/IP communication between computers, Postscript side description language for peripheral units, SQL-based relational database and GKS graphics standard.

REALIZATION

The project had no defined start; for many years it was realized that further development of the existing minicomputer systems had to be terminated. Some preliminary specifications were made in autumn 1987 by the IMR in cooperation with SIMRAD Subsea A/S. These preliminary specifications gave a rough description of the staff´s conception of the new system, and they were the basis of a research project initiated in 1988 with Christian Michelsens Institute in Bergen and supported entirely by the internal resources of the Institute of Marine Research. The first step in this project was systemizing, and in the period January - March there was an intensive meeting activity in which experienced scientists, technicians and experts in computer graphics participated. Desirable features or capabilities were considered in relation to what was possible with present technology. Sometimes the wishes reached far beyond what was possible, but generally the system has become more powerful than anybody initially imagined. The system is described in a system design report [5] and fig.1 shows the network with the different on-line stations.

Main window

Raw data from the EK500 are fetched from mass storage and displayed in the main window (fig.2). The echogram in the main window consists of 1000 horizontal times 500 vertical pixels. Each pixel represents a S_v-value (volume backscattering strength) preprocessed by the EK500. The area backscattering coefficient, s_A, is deduced from the S_v-values. All measurements are absolute because of calibratiom with standard targets [6] that have well defined target strengths (TS). In this way the values are independent of the instrument settings, and they can be directly compared with values from similar instrumentation.

The horizontal distance each pixel represents is selectable between "ping based" and "log based" presentation. In the "ping based" mode, every sounding is presented on the display and in the "log based" mode, 200 soundings per nautical mile are presented. In the latter mode there is always room to present data for 5-nautical-miles sailed distance on the display.

The presented echogram has no other limitations than those set by the pixel resolution. There is essentially no lower threshold, and with the outstanding signal-to-noise ratio in the EK500, one can observe signals with strengths far below what is achieved with conventional instruments. With a dynamic range of 160 dBW, saturation can hardly occur.

Initially the echogram is divided into horizontal depth layers, usually 50-m thick. The operator is free to move the limits between layers, remove limits or add new layer limits. If the registrations are configured in such a way that horizontal division is impractical, it is possible to draw the layer limits with any arbitrary shape and in this way separate one type of registration from another. Schools can be separated in special boxes.

Within each layer in each nautical mile, the s_A value is written. This is defined for a single ping as follows:

$$s_A = \int_{z_1}^{z_2} \frac{\sigma_F}{\psi\, z^2}\, 1852^2\, dz$$

where σ_F is the backscattering cross section of a fish at depth z, ψ is the solid angle covering the equivalent beam of the transducer , and (z_1 ,z_2) are the layer limits. At the end of the current echogram, the average s_A for each 5 NM is given. By pushing and pulling the color scale, the threshold is changed, and recalculated s_A - values appears instantly.

<u>Calibration</u>

The calibration is carried out with a standard target on axis as described in a cooperative research report [7]. The EK 500, however, is a completely digital system, and an analog signal output (calibrated output), as found on conventional scientific sounders, does not exist. Therefore the procedure has to be slightly changed. This change consists in essence of comparing the integral of the standard target to the theoretically calculated integral.

The backscattering cross section of the target ,σ, is related to target strength as:

$$TS = 10 \log (\sigma/4\pi r_0^2)$$

where r_0 is the reference distance, usually 1 m.

The standard sphere represents an area backscattering coefficient, normalized to one square nautical mile (NM^2), given by the equation:

$$s_A = \frac{\sigma}{\psi\, z^2}\, 1852^2$$

where z = sphere depth (m)
ψ = solid angle covering the equivalent beam.

Example:

A copper sphere with diameter 60 mm has the nominal target strength TS = -33.6 dB, hence

$$\sigma = 4\pi r_0^2 10^{-3.36} = 0.00549 \ (m^2)$$

The transducer is circular with a beamwidth of 7.5 degrees. The equivalent beam angle (10 log ψ) is, according to Urick [8]:

$$10\log((7.5/2)^2) - 31.6 = -20.1 (dB)$$

$$\text{thus} \quad \psi = 10^{-2.01} = 0.0097 \ (\text{sterad})$$

The sphere depth is 18.3 m. If a sailed distance of 1 NM is simulated, then the theoretical area backscattering coefficient is:

$$s_A = 0.00549/(18.3^2 * 0.0097) * 1852^2 = 5796 \ (m^2/NM^2)$$

The output from the echo integrator should agree with the theoretically calculated value and if it deviates, the EK500 has to be corrected or adjusted.

Bottom window

Permanently connected to the main window is a bottom window displaying the echo record 10 m above and 5 m below the bottom, as detected by the echo sounder. The vertical resolution of this window is 10 cm according to the 7.5 kHz sampling frequency of the digitizer in the EK500. In case of bad conditions, the echo sounder may fail in bottom discrimination. The contribution of the bottom echo from a single sounding is so large that it can be disastrous for the integrator values in the interval. With a mouse-operated cursor, the operator is free to draw a new bottom line and thereby correct the bottom line anytime after the measurements have been made.

It is emphasized that the basic limitations, such as the blind zone close to the bottom, cannot be avoided in this system, but data for the density immediately above the bottom are so detailed that one can do a statistical analysis and calculate the probable density in the blind zone.

Auxiliary windows

In order to split the s_A-values and apportion them to the different species, a special interpreting window (fig.3) is used. This window shows the most vital data for the actual layer and log interval. The total s_A-value is presented and from a menu the operator selects the actual species and allots their parts by means of scroll bars. The percentage distribution is shown, and in the next log interval the layer divisions and percentage distributions are carried over. Very often the patterns and distributions repeat in trailing log intervals, and for economy in operations, one can simply press the "ready" button.

A common problem for many acoustic surveys is the weather conditions. Continuous wind causes air bubbles in the upper layers, and the air is an effective attenuator of sound in water[8,9]. As an attempt to solve this problem, the interpreting window allows input of a "bubble correction" factor.

During acoustic surveys the concurrent interpretation of echograms and integrator values are of extreme importance. The most important supplemental information in the interpretation session is catch data from trawl stations and data from hydrographic stations on the site. It is stressed that the new system should help the completion of this process in the most effective way.

FIRST SEA TRIALS

In December 1988 the first sea trial was carried out on board R/V"G.O.Sars". The EK500, which in addition to be an advanced echo sounder, is a powerful digital processor, was installed in its preliminary test version. The transducer used was the former split-beam model designed for the ES380. The software, far from finished, was able to process the echo signals and send them on the Ethernet. Thanks to the advantages of standardization, the echogram data were transferred with a minimum of connections (a single coax cable) and reproduced on the workstation's CRT from the first moment.

The trial started with a calibration session at Skogsvaagen in the vicinity of Bergen and continued along the coast between Bergen and Trondheim with detours in some fjords. The calibration was carried out with standard targets with TS = -42.3 dB and -33.5 dB. In addition, in order to check the linearity of the system, copper discs with TS up to +14.0 dB [10] were applied.

In this way the equipment was tested against controllable targets within a range of 56 dB and neither nonlinearities nor tendencies towards saturation were observed. The great dynamic range and the superior signal-to-noise ratio in the echo sounder is reproduced very well if partially on the display of the workstation, which can show S_v-values between -91 dB and -12 dB. This graphic presentation has a greater dynamic range than that of any former echo sounder. Reverberation from the smallest organisms appears as grey clouds and usually this has to be thresholded to achieve good contrast with the fish echoes.

The best fish registrations were made on a shoal of herring in Vinjefjord. This was measured continuously during 24 hours and day/night variations were observed in the density distribution.

With the new equipment it is possible to store the raw data with high resolution for later studies of the density distribution in the shoal or school in detail. In order to take care of the registrations for later shore studies, the data were copied to 60 megabyte streamer tapes. In this way echogram data are stored without any reduction of the quality.

The second sea trial was carried out in March 1989 in northern Norway. The ES38B transducer, specially designed for the EK500, was installed. In addition a tranceiver of 120 kHz was installed. Unfortunately we had to use a nearly 20-year-old 120-kHz transducer, which did not match very well to the echo sounder, but it worked well enough for a function test. The workstation was prepared to log data simultaneously from two transducers and this was tested without observing any capacity problems due to a doubled data rate.

Several PC-based stations were connected to the local network and data from the STD-logger (salinity, temperature and depth) and trawl-catch data were sent to the data base. The corresponding auxiliary windows were tested (fig.4).

EXPECTATIONS

The B.E.I. in its present development stage per June 1989 has been permanently installed on board R/V "G.O.Sars" and R/V "Michael Sars". It remains to test it in routine situations around the clock, week after week. The feedback from planned surveys will determine the priority for the further development of the system, which has an enormous potential for expansion. It is planned to develop software that utilizes the collected primary data to calculate fish stock sizes. By the end of a survey, electronically generated maps for the fish stock distribution should be available. These results, however, are only parts of the total stock assessment. Through compatible or similar SQL-based data base systems, survey data can easily be transported from the vessels to the database ashore for combination with fisheries statistics and data from other vessels and cooperating nations in order to carry out the final calculations.

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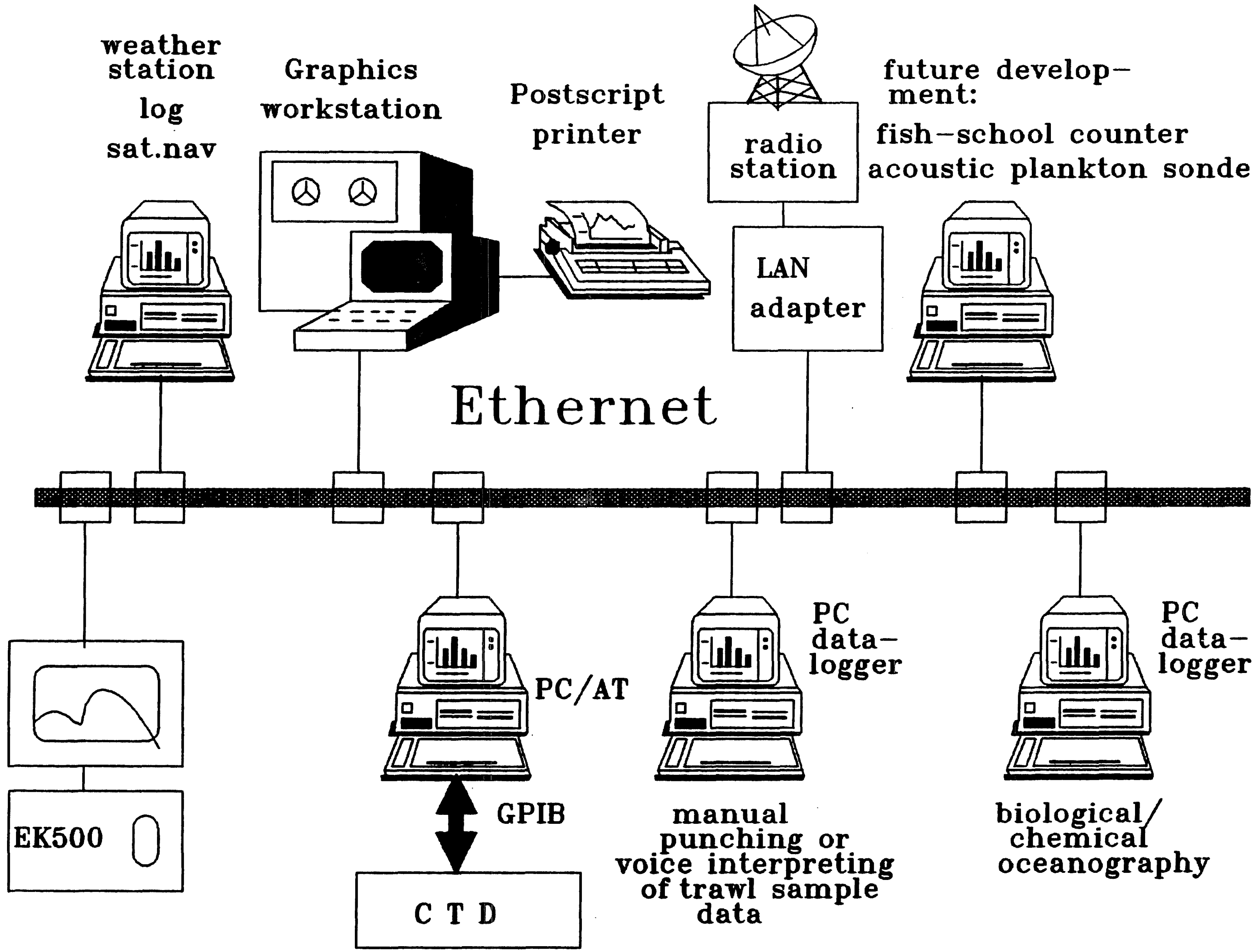

Figure 1. Local Area Network

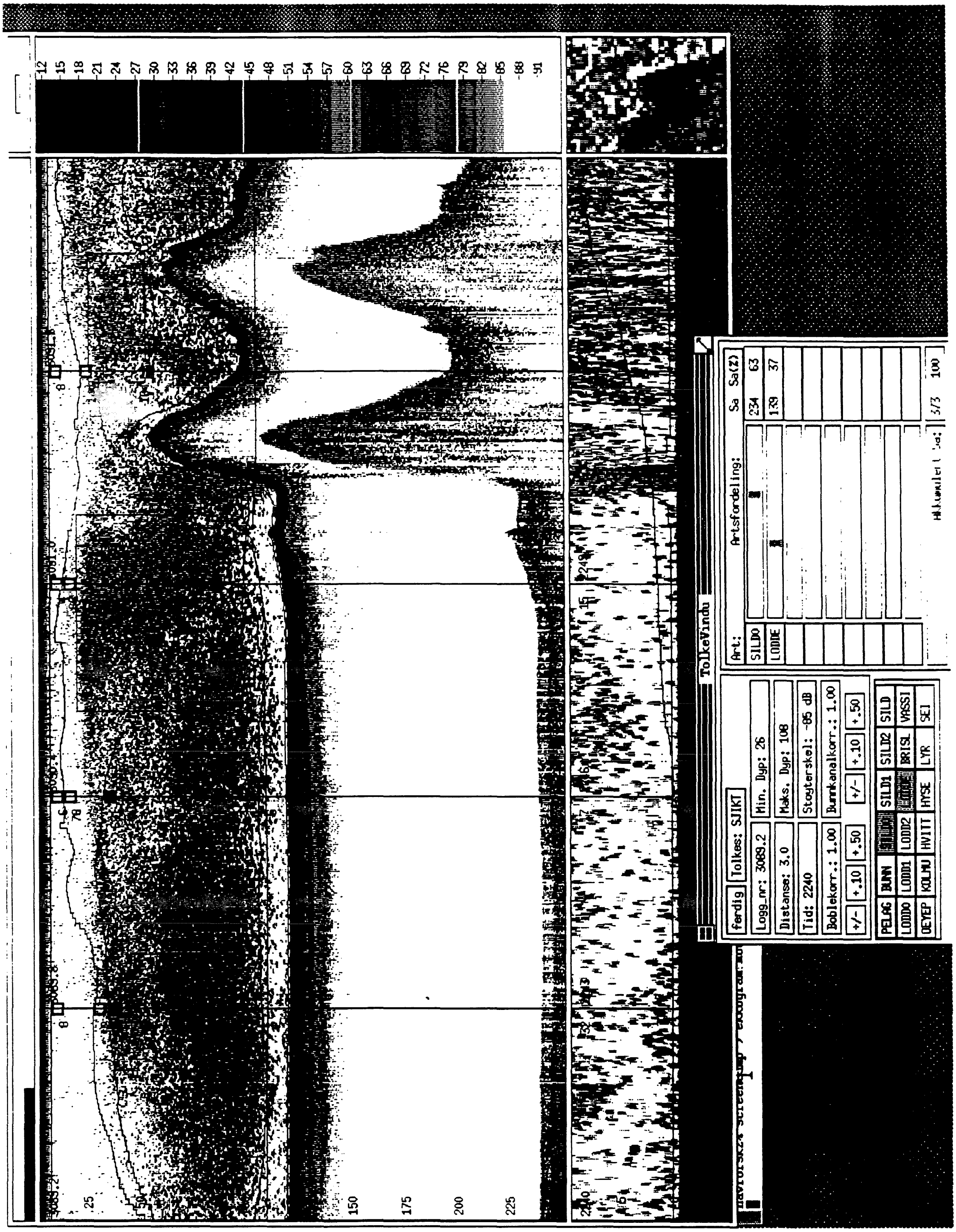

Figure 2. Screendump including main window, bottom window and interpreting window.

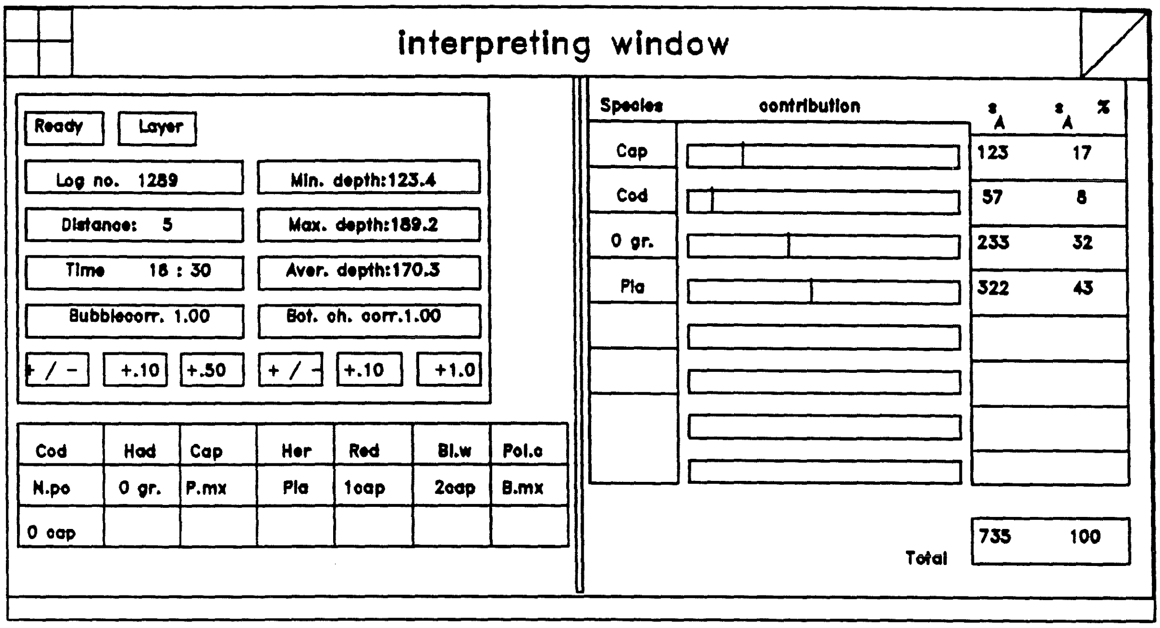

Figure 3. Interpreting window.

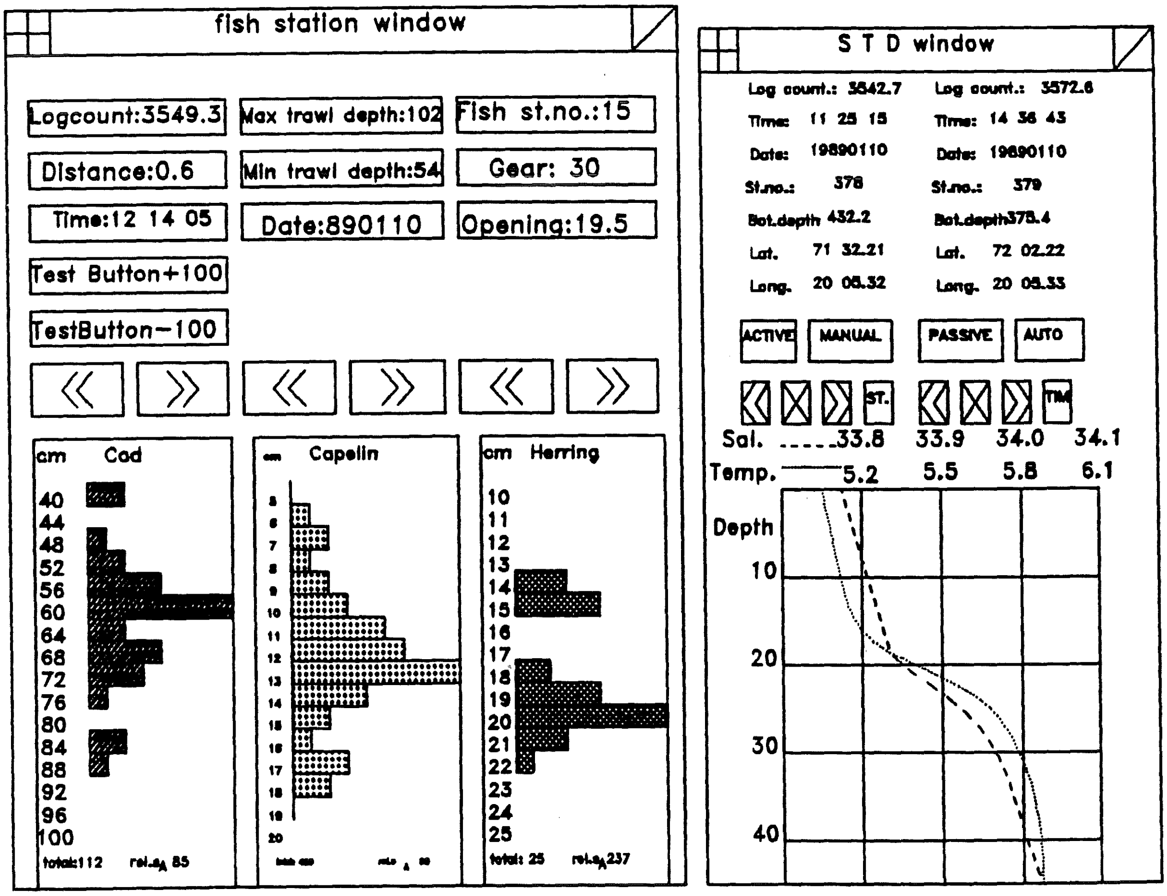

Figure 4. Auxiliary windows.